University of BRISTOL

PAPR Reduction for Single Carrier FDMA LTE Systems using Frequency Domain Spectral Shaping

Zuhanis Mansor,

Prof. Andrew Nix and Prof. Joe McGeehan

Presentation Outline

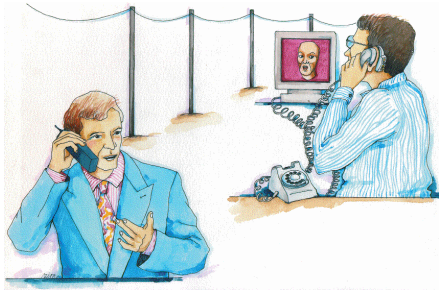
- ✓ 3GPP LTE uplink transmission – Single-Carrier Frequency Division Multiple Access (SC-FDMA).
- ✓ PAPR comparison of SC-FDMA with distributed and localized subcarrier mapping schemes.
- ✓ Investigate the impact of PAPR through frequency domain spectral shaping with localized sub-carrier mapping.

Introduction

- ✓ Generations of Mobile Networks
  - 1G, 2G, 3G ⟶ **4G** (are currently in development around the world)
  - Mobile phone plays an important roles – business or social networking
  - 'smartphone'
- ✓ Limitations – network coverage, capacity...
  - Battery life – a key parameter that affects all mobile handsets.
  - Even though the battery technology is improving
    - To ensure that mobiles phone **use as little energy as possible**

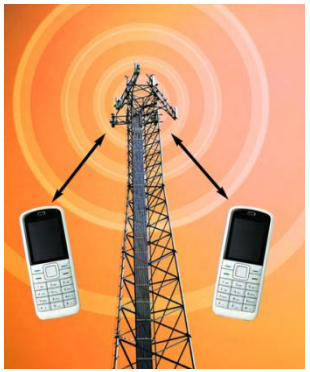
4G- Wireless & Mobile Technology

Wired communication

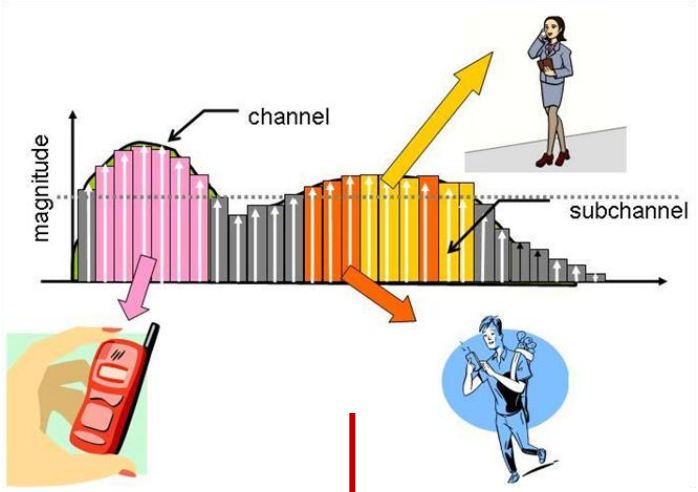


1G (Analog)

2G (Digital)
3G (W-CDMA)



Orthogonal frequency- division multiplexing (OFDM)

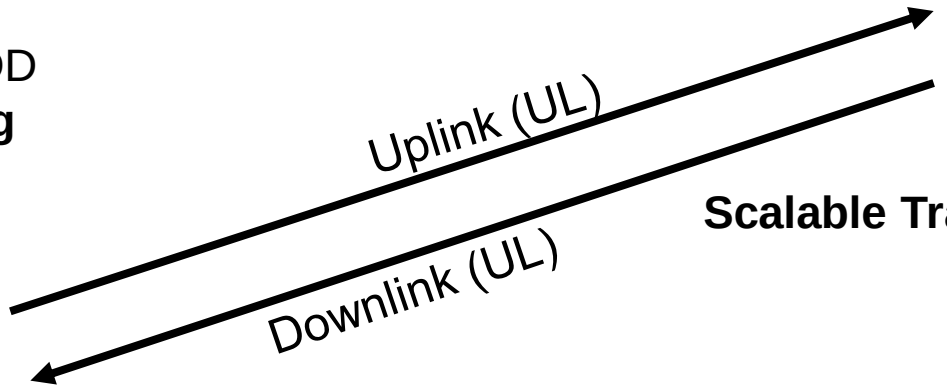


PAPR ???

- OFDMA
- SC-FDMA

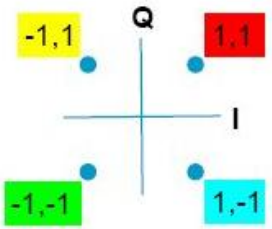
3GPP LTE (Long-Term Evolution)

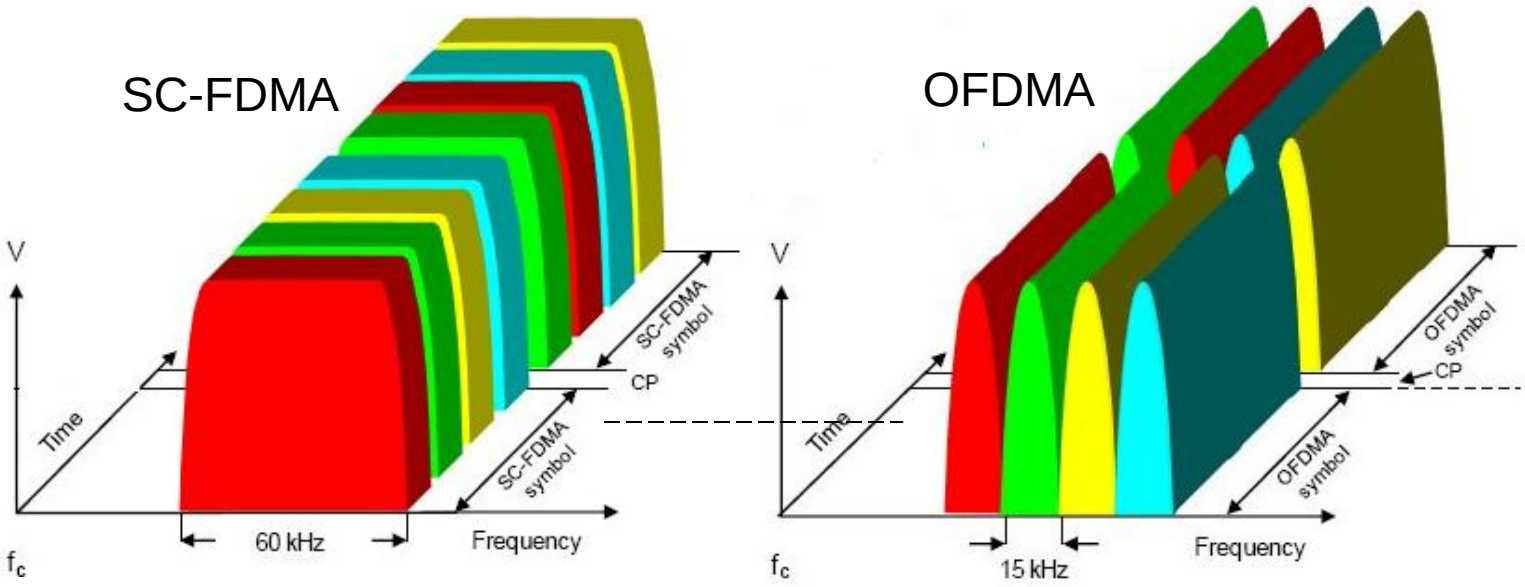
Scalable Transmission Bandwidth (MHz)
1.4, 3, 5, 10, 15 & 20
Adaptive Modulation
QPSK, 16QAM & 64QAM
Duplexing
FDD and TDD
Multiplexing
SC-FDMA



Scalable Transmission Bandwidth (MHz)
1.4, 3, 5, 10, 15 & 20
Adaptive Modulation
QPSK, 16QAM & 64QAM
Duplexing
FDD and TDD
Multiplexing
OFDMA

SC-FDMA vs OFDMA



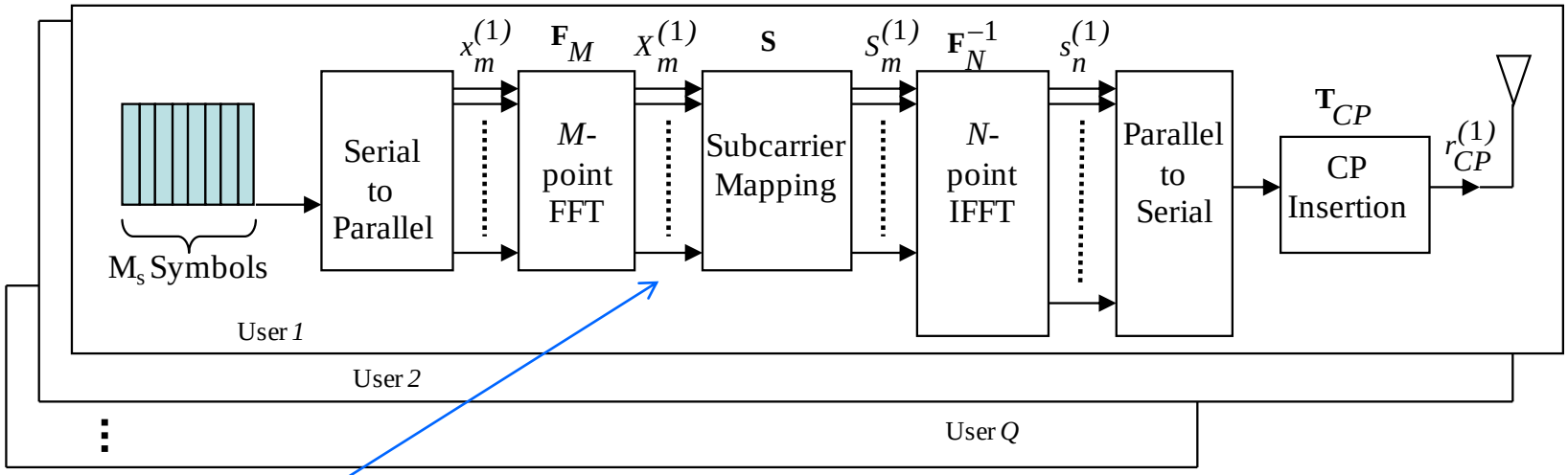


Data symbols occupy M*15 kHz for 1/M SC-FDMA symbol periods

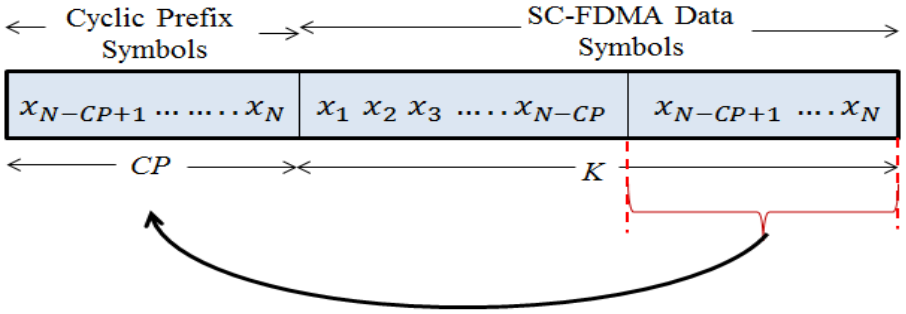
Data symbols occupy 15 kHz for one OFDMA symbol period

- ✓ shows how a sequence of eight QPSK symbols is presented in frequency and time domain

SC-FDMA Transmitter System



$$\mathrm{FFT}\{x_m\} = X_m^{(k)} = \frac{1}{\sqrt{M}} \sum_{n=0}^{M-1} x_m e^{-j\frac{2\pi}{M}nm}$$

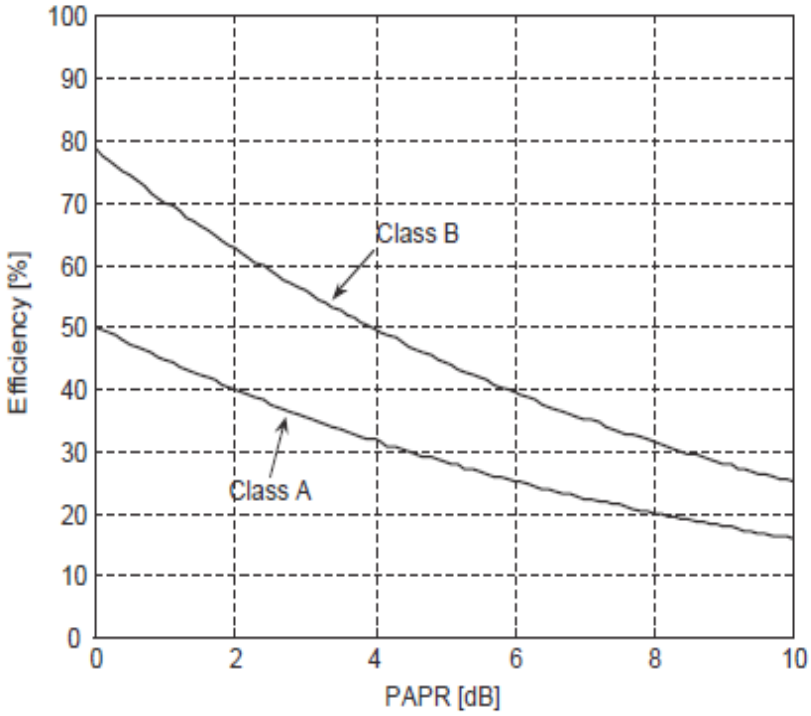


PAPR and Power Amplifier Constraints

- Peak-to-average power ratio (**PAPR**) problems occur in broadband communications causing power amplifier distortion issues.
- It also results in received errors as well as reducing **power efficiency** and **battery life**.
- Amplifiers must be specifically designed to cope with this problem, and this increases their cost.

PAPR

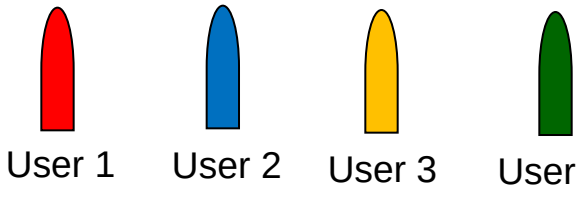
- Peak-to-average-power ratio (PAPR) is a performance measurement to indicate the power efficiency of the transmitter.
- Figure shows the theoretical efficiency limits of linear amplifier.
- High PAPR degrades the transmit power efficiency performance.

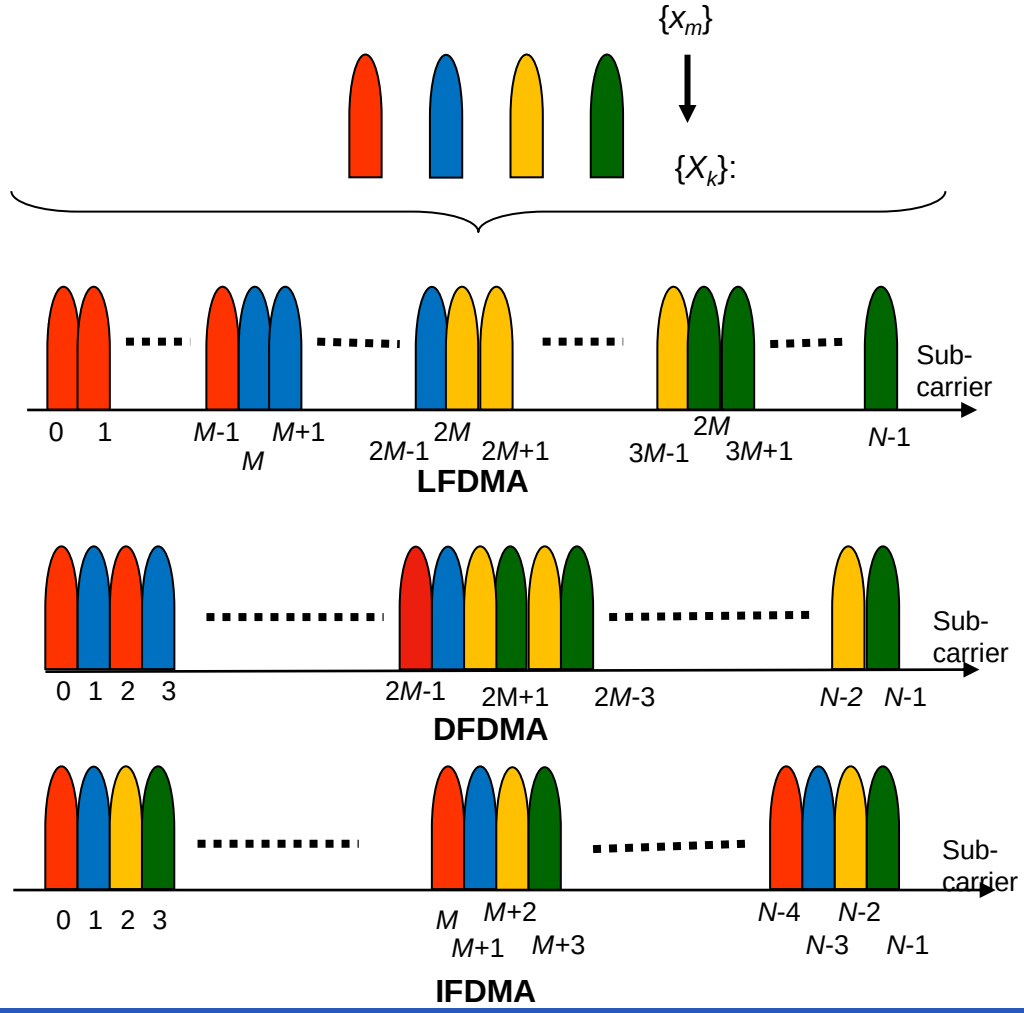


$$P_{PAPR}(i) = 10\log\left\{\frac{\max_t\{|x_{tx}(t,i)|^2\}}{E[|x_{tx}(t,i)|^2]}\right.$$

SC-FDMA Subcarrier Mapping Schemes

- ✓ LFDMA, DFDMA and IFDMA demonstrating that signals of the four (4) different terminals arriving at a base station occupy mutually exclusive sets of subcarriers.
- ✓ *M* symbols per block, *N* subcarriers and *Q* users.

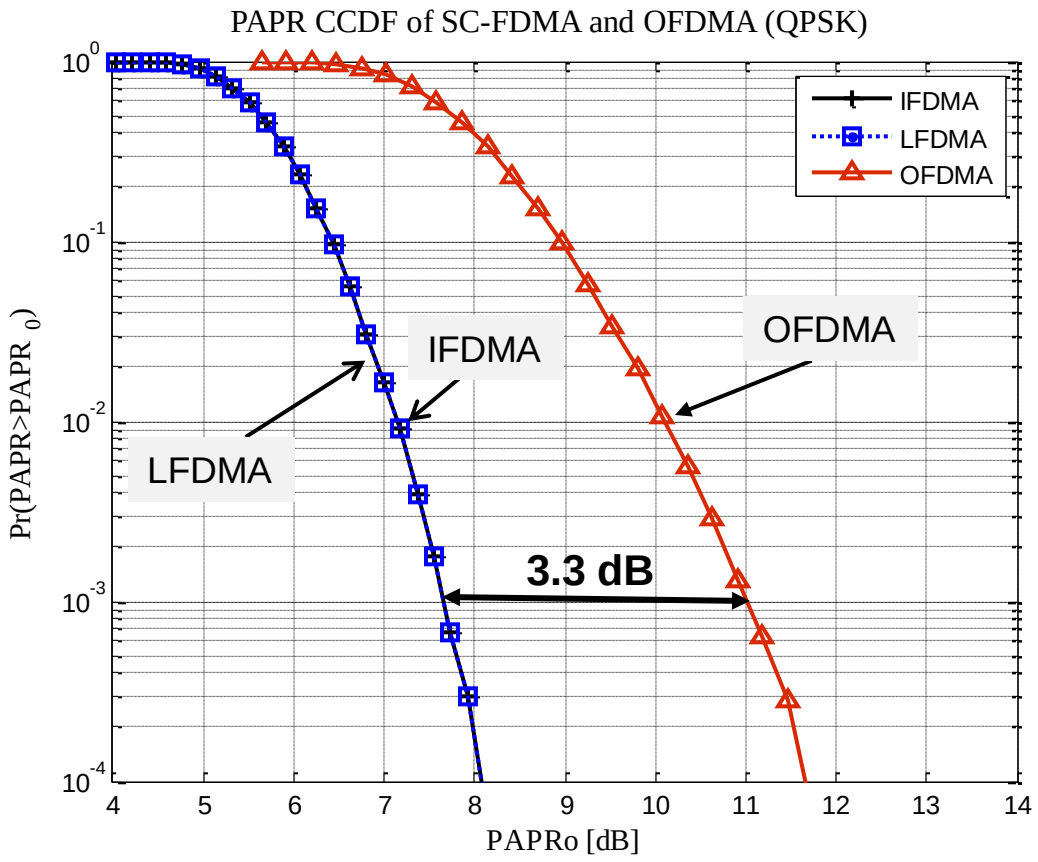




Simulation Parameters/Assumptions

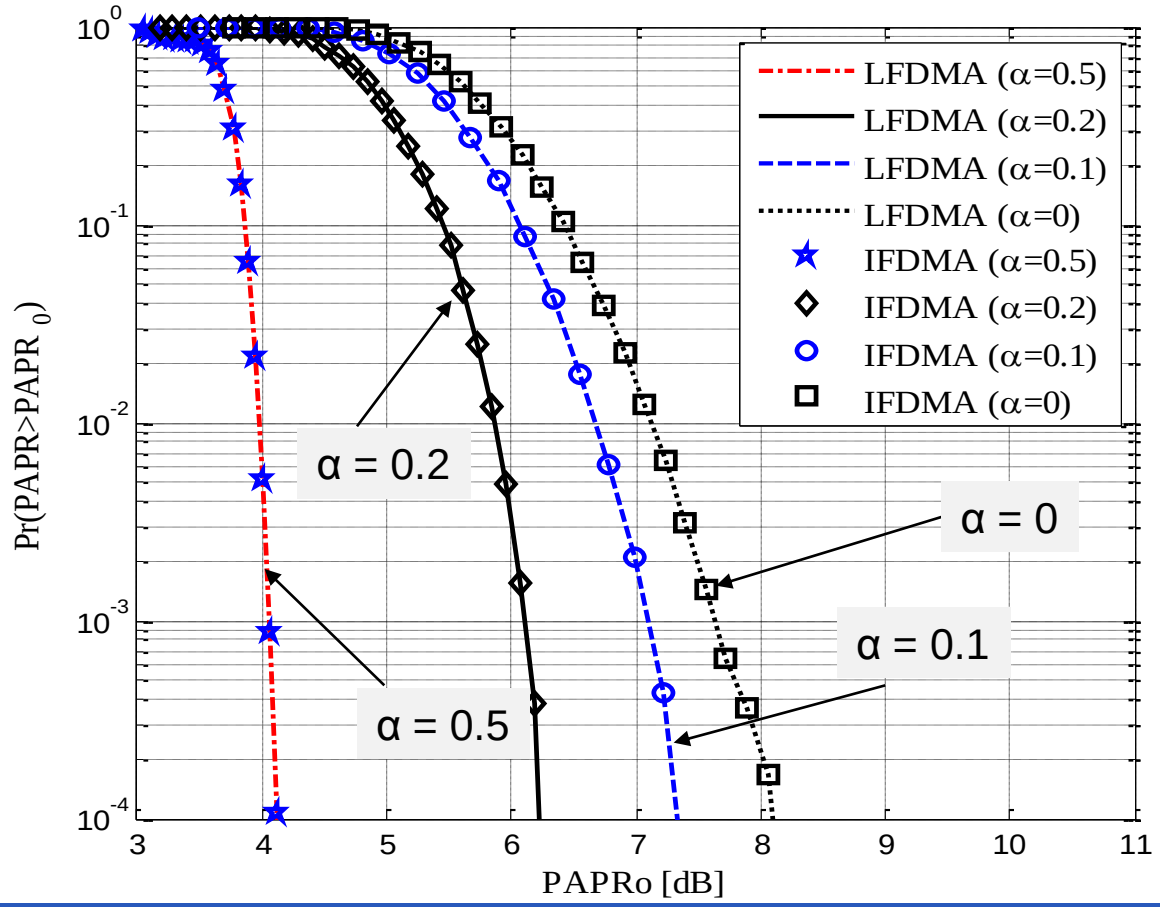
Parameter	Value
Carrier Frequency	2 GHz
System bandwidth	5 MHz
N-size IFFT	512
M-size FFT	128
Modulation scheme	QPSK, 16QAM
Cyclic prefix	32 samples (6.4 *μs*)
Antenna scheme	SISO

PAPR Comparison of Time Domain Pulse Shaping Filter



- ✓ LFDMA and IFDMA both have significant PAPR improvement compared to OFDMA.
- ✓ OFDMA exhibits a higher PAPR compared to LFDMA and IFDMA.
- ✓ SC-FDMA exhibits a lower PAPR compared to OFDMA because of its single carrier structure.

The Impact of Pulse Shaping on the PAPR of SC-FDMA signals



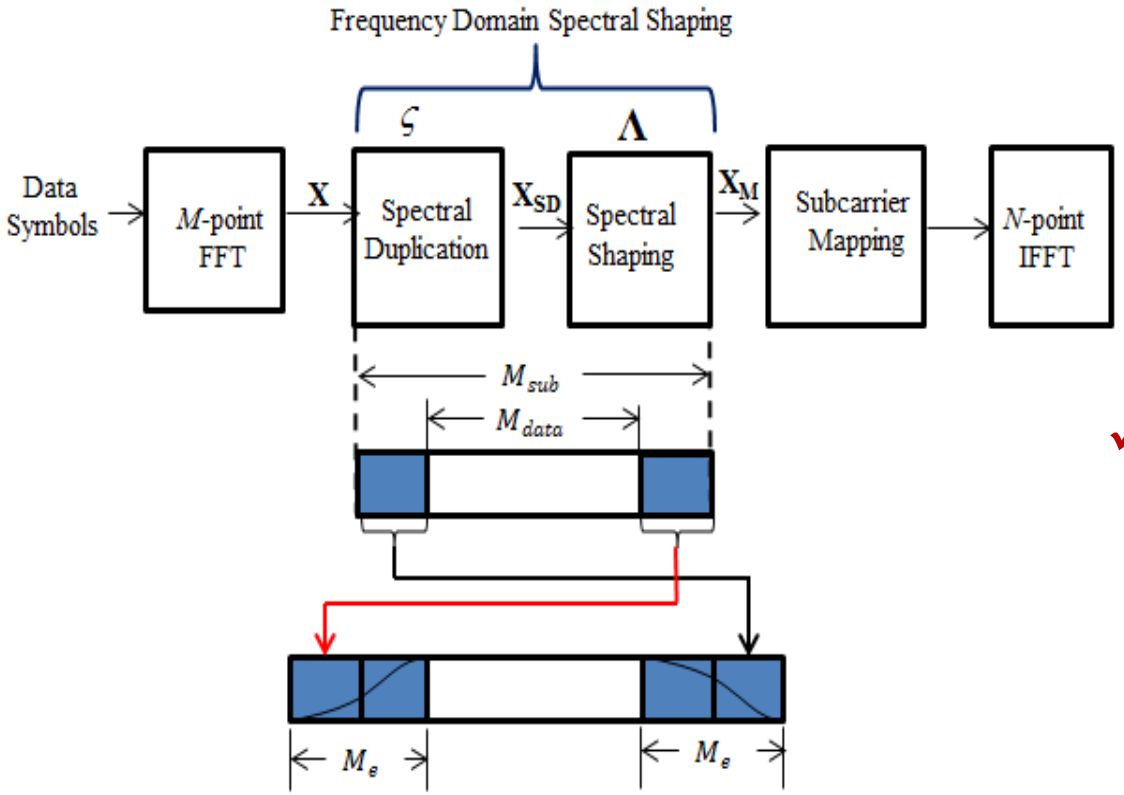
QPSK

- ✓ PAPR *decreases as roll-off-factor (α) increases.*

Frequency Domain Spectral Shaping (1)

- ✓ What is the difference between the time domain pulse shaping used in traditional single carrier systems and the frequency domain spectral shaping used in SC-FDMA?
  - A traditional time domain pulse shaping filter is used to band limit the transmit signal.
  - However, the frequency domain spectral shaping process is applied to reduce PAPR.
- ✓ The PAPR of SC-FDMA signals with RC frequency domain spectral shaping is now further investigated.

PAPR Reduction via Spectral Shaping



- ✓ The SC-FDMA uplink requires pulse shaping to limit the inter-symbol interference (ISI) between neighboring time symbols
- ✓ Frequency domain spectral shaping can be used in SC-FDMA to achieve PAPR reduction

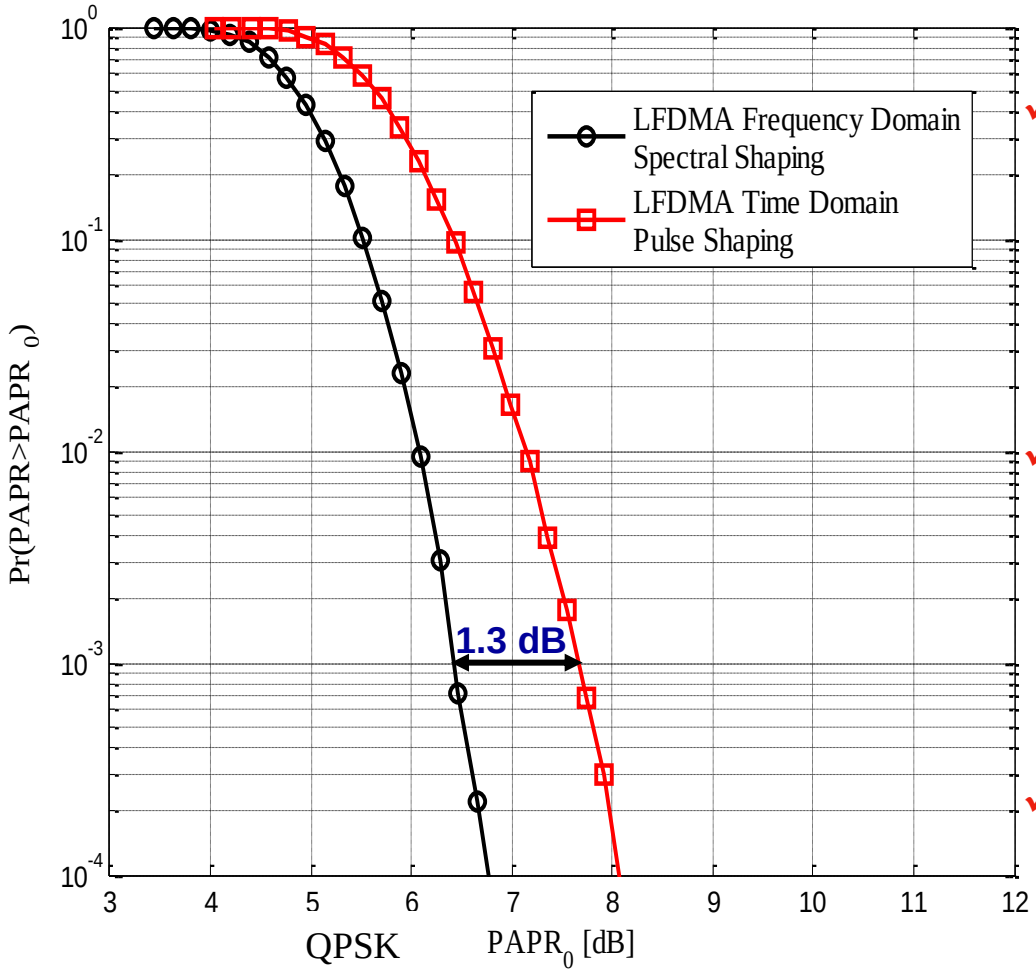
PAPR and Bandwidth Efficiency

Comparison of PAPR and bandwidth efficiency using RC frequency domain spectral shaping at α = 0.2 with QPSK modulation.

Bandwidth Efficiency	78.1%	85.9%	100%
PAPR of LFDMA at CCDF = 10^{-3}	6.4dB	6.6dB	7.7dB

- ✓ The number of transmit data symbols, M_{data} = 100, 110 and 128.
- ✓ The PAPR of SC-FDMA signals can be reduced at the cost of degraded bandwidth efficiency

PAPR Reduction



- PAPR of SC-FDMA for LFDMA employed RC frequency domain spectrum shaping and time domain pulse shaping with QPSK signaling at α = 0.22.
- Results show that a PAPR reduction of 1.3 dB can be achieved for QPSK when RC frequency domain spectral shaping is used with roll-off factor of 0.22.
- Compared to the unfiltered version, the bandwidth efficiency is reduced to 78.1%.

Conclusions

- ✓ SC-FDMA is suitable for uplink transmissions as it has a lower PAPR than OFDMA (since it improves the power efficiency of the mobile transmitter).

- ✓ In this paper we have shown that by applying a frequency domain spectral shaping filter, the PAPR of a localized FDMA (LFDMA) signal can be further reduced (1.3 dB) at the expense of degraded bandwidth efficiency (78.1%).

- ✓ The resulting PAPR reduction can be used to enhance handset power efficiency, or alternatively to improve uplink throughput and/or operating range.

University of BRISTOL

Thank You

Zuhanis Mansor, Prof. Andrew Nix and Prof. Joe McGeehan
[Anis.Mansor@bristol.ac.uk]